Implications of end-user behaviour in response to deficiencies in water supply for electricity consumption – a case study of Delhi

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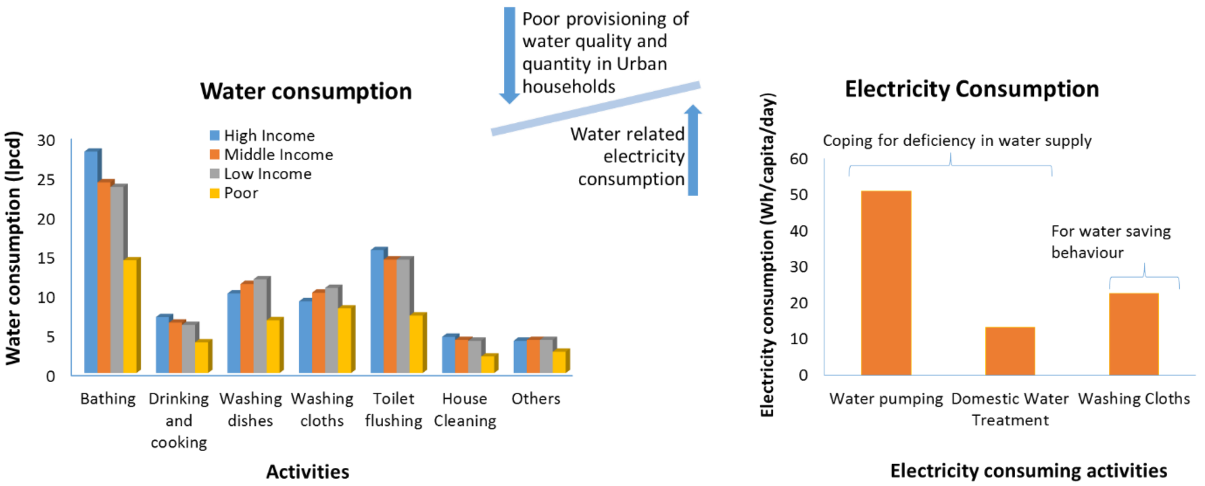
Graphical Abstract



Highlights

- Water and electricity consumption studied in Delhi.
- Lifestyle changes and use of gadgets influence domestic water consumption.
- Daily per capita water requirement for basic needs at home is 76 litres.
- Water-related energy consumption per capita in organized housing is 3.25 kWh/month.
- Nearly 70% of electricity is used for coping with poor water supply.

Abstract

Over the past two decades, urban lifestyles have changed phenomenally. One aspect of this change is the increasing use of household appliances, which, in turn, influences water and electricity consumption in urban households. It is therefore necessary to revisit water supply norms in view of these behavioural changes. Increasing use of water-related appliances by the surveyed households in Delhi, India has lowered their water consumption but increased their electricity consumption (10–16 kWh a month). Also, longer working hours away from homes have shifted water demand from homes to commercial establishments and institutions. The per-capita water requirement to meet the basic needs for health and hygiene is approximately 76–78 litres a day, of which bathing claims the largest share (32%). Nearly 70% of electricity consumption of a household is spent in coping with deficiencies in water supply. Strategies adopted by end users to save water were negatively correlated with those to save electricity. Household incomes have no influence on water consumption except in the case of those living in slums, who are forced to curtail their use of water even at the cost of health and hygiene; for the rest, coping with poor water supply amounts to spending nearly 50% more on electricity, defeating the purpose of subsidized water supply.

Keywords:

Domestic water demand, Electricity consumption, Household water use, Water saving strategies, Water-use related appliances

1. Introduction

Water and electricity are two most critical resources provided by urban utilities to residents. Equitable access to and adequate supply, and responsible consumption of, these resources are central to achieving key policy goals such as poverty alleviation, health, sustainable cities, low carbon growth, vulnerability reduction, and improvement in the quality of life (ADB, 2004; SEI and UNDP, 2006; Wang et al., 2004; WWAP, 2015). In many countries, water and electricity are resources in limited supply (GEA, 2012; SAPIENS, 2005; WB, 2002), and most of these countries have low per-capita incomes; therefore, the state needs to supply the resources at subsidized prices, and the consumers need to use the resources judiciously (UN, 2007; WWAP, 2014; WB, 2005).

People's behaviour related to resource use is influenced by their level of awareness, income, price of the resource, and perceived risk of resource scarcity and its impact on the quality of life (Janda, 2011). Of these factors, price and risk perception have proved the most effective in bringing about positive behavioural changes in electricity usage by urban households in many developing countries (Stamminger and Anstett, 2013). However, the same cannot be said of sustainable use of water (Randolph and Troy, 2008). Supply of water is often made mandatory for governments by the constitution (IELRC, 2010), and its price is highly subsidized because it is considered a common resource and access to water, a basic human right. However, water-related infrastructure in cities has capital and operating costs, which need to be recovered through fees or tariffs, and this makes water an economic resource(Hanemann, 2005). Therefore, to ensure sustainable water supply to all, to promote responsible use of water, and to make water utilities financially autonomous will require a differential pricing structure (NIPFP, 2003). Governments in developing countries are experimenting with the idea of supplying water to people at subsidized prices to meet the basic needs and at higher prices to meet other needs beyond the basic needs (*Financial*

Express, March 2015). However, such policies require high-quality data on water consumption by households from different socio-demographic backgrounds or strata to ascertain their 'basic needs' for planning appropriate demand-management interventions and for encouraging people to conserve water and to use it efficiently (Jorgensen et al., 2009). Unfortunately, such high-resolution data are not available, especially in developing countries, because water meters to measure total domestic water consumption are rare, and smart meters that can measure the amounts of water used for different activities are virtually unknown.

It was against this background that the present study sought to examine the pattern of water consumption in the domestic sector in Delhi. More specifically, the study sought answers to the following questions: (1) How does per-capita consumption of water at home vary with the socio-economic and demographic status of the household? (2) How do the strategies that people use to cope with inadequate and erratic supply of water of questionable quality influence the total household consumption of water and of electricity? (3) How does the demand for water change with the use of modern water-related appliances? The study also examines the water–energy nexus related to water infrastructureat the level of urban households.

The study is important given the fact that water demand is influenced by a number of intersecting cultural, climatic, demographic, infrastructural, social, and physiological factors (Fan et al., 2014; Willis et al., 2013). The greater penetration and use of modern appliances in urban households influence the consumption of water (which is typically lowered) and of electricity (which is typically increased) (Schuetze and Santiago-Fandiño, 2013). However, urban planners assess a city's water demand through only one simple statistic, namely the recommended or normative per capita water supply: a figure that has not been revised for decades, does not appear to reflect social equity, is not supported by any explicitly stated rationale—and is widely variable. In India, for example, the norms, in litres per capita per day (lpcd), are as follows: 200 as the minimum for domestic consumption in cities with flush toilets, 135 for low-income groups and weaker sections of society, 40 for those collecting water from community taps (BIS, 1993), 150 for megacities and other metropolitan cities, 135 for cities with piped water supply and planned sewerage systems, and so on (Planning Commission, 2007). The World Health Organisation classifies water supply in four different categories and suggests 100–200 lpcd as the optimal figure (WHO, 2003). There is little evidence that these norms are based on any real demand assessment.

2. Evidences from past studies

Estimates of daily per-capita water consumption have varied with the country: 45–70 L in some African countries (Gulyani et al., 2005), 140–350 L in European countries and Australia (Willis et al., 2013), 322 L in Japan (WB, 2006), 136–242 L in USA (Novotny, 2010), and 70–200 L in Asian cities (Gunatilake et al., 2001; Tortajada, 2006). Such estimates vary even within a country, from city to city (Willis et al., 2013). These estimates are mostly from studies with various research objectives and based on different methods. For example, analysis done on pattern of water consumption in Gold Coast City, Australia to understand water-related behavioural changes among different socio-economic groups and the adoption of water-saving devices (Willis et al., 2013). The researchers used a mix of methods including questionnaire surveys and smart meters. Shaban and Sharma (2007) used a questionnaire to assess household water consumption and conservation efforts in seven Indian cities to understand how socio-economic strata influence end use. Other studiescompared water consumption in metered and unmetered households to quantify and characterize the end uses and the effectiveness of demand-side management in households (Beal et al., 2013; Renweek and Green, 2000).

Despite the variations in methodologies, objectives, and results, some generalizations can be made from these studies. First, independent dwellings tend to consume more water than apartments or flats because some water is used for gardening (Kenney et al., 2008). On the other hand, independent dwellings offer greater incentives for saving water because (1) the occupants benefit directly from such savings; (2) it is easier to identify water-intensive activities, and (3) the occupants can make the relevant decisions independently (Randolph and Troy, 2008). Second, water consumption of a householddepends on the ages of its members. For example, younger occupants consume less water on average but show greater temporal variation in water demand: they use the dish washer only occasionally, the washing machine once a week, and typically wash their cars twice a month. The young also account for more specific, activity-driven, consumption such as bathing, extensive washing, and brushing teeth. Third, water consumption within the same country varies with the city, being more in cities in which water is subsidized (WSP, 2002).

3. Description of the study area

Delhi is India's capital city: it is predominantly residential, with significant commercial spaces and some industry, mostly in the form of small and medium enterprises. The tertiary sector of economy contributes approximately 88% of Delhi's GDP (GNCTD, 2015a). The average annual per-capita income in 2013/14 was 212,219 Indian rupees (INR) (GNCTD, 2015a), which is double the national average. Climate is similar to that of temperate grasslands, with harsh summers and severe winters (Khare and Kansal, 2004). Delhi has a population of 16.8 million, living in 3.34 million houses spread over 1483 km^2(GNCTD, 2014a; GNCTD, 2014b). The Delhi Development Authority (DDA) is responsible for city planning; it is also the major supplier of housing in the city and classifies dwellings into four major categories based on area: EWS (less than 30 m^2) for Slum-dwellers or for

Economically Weaker Sections; LIG (30–40 m^2) for those in the low-income group; MIG (40–80 m^2) for those in the middle-income group; and HIG (more than 80 m^2) for those in the high-income group (DDA, 2010). In addition to these, there are privately built individual houses, apartments built by real-estate developers, and some unauthorized settlements, mostly slums.

Water supply infrastructure is managed by the Delhi Jal Board (DJB; *jal* is Hindi and Sanskrit for water), which is an autonomous department of the Government of Delhi. The board supplies about 3.8 million m^3 of water a day (GNCTD, 2015b). Losses in distribution system are estimated at 30%–40% (GNCTD, 2015b). Approximately 73% of the households have piped water supply, 14.3% depend on community taps, and the rest depend on tube-wells and tankers, which bring water to the doorstep of users (GNCTD, 2014). Even in the case of piped water supply, the amount varies with the locality, and supply is typically intermittent, for a few hours each in the morning and in the evening (Shaban and Sharma, 2007). Pressure in the distribution system is low during the period of peak demand. Water tariff is either volumetric (based on actual consumption, which is metered) (DJB, 2015) or flat, in the form of a fixed monthly charge (WSP, 2011). Multiple sources (piped supply, groundwater, tankers, and so on) mean that water consumption can be estimated only through a primary, first-hand inventory.

4. Methods

A variety of approaches were used for collecting and analysing different types of data required for various objectives of the study. These approaches were drawn from the methods and techniques used in quantitative and qualitative research (Clark and Creswell, 2007). Questionnaires and interviews were used for obtaining data on the following aspects: socio-economic and demographic attributes of respondents, sources of water, risk-averting behaviour of households, behaviour related to water use, stock of water-related household appliances, and the monetary cost of obtaining safe water. The data were supplemented with simulated experiments on select groups of volunteers to measure water consumption for various end uses. Data on electricity consumption and water requirements of different appliances were assessed using information from the manufacturers' catalogues.

4.1 Questionnaire survey and design

All households in Delhi were considered for the sampling frame. Semi-purposive sampling was used since the study required respondents from a broad spectrum of households (Crona et al., 2009; Sovacool et al., 2012). The survey was conducted from May to July 2014 and from March to April 2015 through personal interviews in the homes of the respondents by graduates in environmental studies, who were given special training for conducting the survey. The sampling frame comprised the computerized records of household electricity connections given by the Delhi Vidyut Board (Kansal et al., 2011) and a list of slum households maintained by the Delhi Urban Shelter Improvement Board. A total of 2800 households were selected for the survey, 700 each from the four housing categories mentioned in Section 3 (Slums, LIG, MIG, and HIG). Adult members of the household were chosen as respondents for the survey. Of the selected households, only 496 cooperated fully (394 in May–July 2014 and 102 in March–April 2015), and their responses were considered for data analysis.

The cardinal qualitative information was recorded in the form of numerical codes. The first section of the survey included general information such as name, address, and telephone number of the respondent (these details were used only for identification purposes). The second section included questions on socio-economic and demographic characteristics of the respondents, such as age, education, general awareness of challenges related to water faced by family members, family size, income and occupation of family members, and sources of water. The third section included an inventory of water-consuming activities recorded in the form of code numbers. For each coded activity, further information required to estimate the water consumption was sought. Depending on the nature of the activity, such information included frequency and duration of the activity, whether individualor collective, etc. If the frequency was once a week, the estimated water consumption was divided by 7 to arrive at the daily consumption. Water used in minor activities was estimated by the enumerators through a set of pertinent questions. The fourth section included information on household behaviour related to water consumption and on relevant household appliances (capacity, make and model, and nature of use). Information about risk-averting behaviour was captured in the fifth section and included information on perceptions of the adequacy of quantity and quality of water and information required for estimating water and electricity consumption for each risk-averting activity. The information sought under this section was cross checked with that sought under the earlier sections. The sixth and final section sought information on total monthly expenditure on water, namely the amount paid for water (whether in the form of charges paid to the DJB or to private parties, suppliers of water tankers, and so on) plus the expenses related to the risk-averting behaviour.

4.2 Simulated experiments and estimation of water consumption for each end use

Experiments were performed during May–June 2015 with the help of five graduate students to estimate the quantity of water used by an individual for each activity that requires water but is not related to any appliance. The activities were timed with a stopwatch and the consumption of water, in litres, measured with graduated vessels. The data in each case were the average of ten observations (each experiment was repeated ten times). Standard water fixtures were used during the experiments. For collective household activities, as distinct from individual activities, similar experiments were performed to measure the water used for washing clothes manually and for washing the dishes (including pots and pans) and the results were estimated in terms of litres per minute. This figure was arrived at by dividing the total amount of water used for a full cycle of washing by the time taken. Water and energy consumed in appliance-based activities were estimated by taking the average of values given in the manufacturers' catalogues. Water and energy used in storing the water to meet the daily needs for drinking and cooking were based on the responses to the questionnaire and from manufacturers' catalogues for domestic water treatment systems.

4.3 Data analysis for water consumption and electricity use

Total water use was estimated using Equation 1.

$$Q = \frac{\sum_{i=o}^{n} q_i}{FS} \quad (1)$$

where Q is total water used (lpcd), n is number of water-related activities of a household, FS is family size (number of individuals), and q_i is water used by the household for ith activity in litres per day (lpd) estimated using Equation 2.

$$q_i = \frac{f_i \times c_i}{7} \quad (2)$$

where f_i is the frequency of ithactivity in the household in a week, c_i is the water consumed in litres (L) during ith activity, and 7 is the number of days in a week.

Data for $c_i$were the measured values for non-appliance-based activities and from manufactures' catalogues for appliance-based activities.

Electricity consumption (E_l, in watt-hours per capita per day) from water-related appliances was estimated using Equation 3.

$$E_l \frac{\sum_{i=0}^{n} E_{pi}}{FS} \quad (3)$$

where E_{pi} is the electrical energy used in ith activity (in watt-hours (Wh) per day) estimated using Equation 4.

$$E_{pi} = P_i \times T_i \quad (4)$$

where P_i is the rated power of i^{th}electrical appliancein watts (W), T_i is the number of hours i^{th} appliance is used daily (h/d), averaged over a week.

Some assumptions and system boundaries: water-related activities performed occasionally (fewer than once a week) and those performed outside the house (having a car washed in a garage, for example) were ignored; energy used for heating water for cooking or bathing was not considered; and water loss due to leakages was not accounted for.

5. Results and discussion

Table 1 shows the descriptive statistics of the surveyed population for each housing category. For further analysis, the data were pooled to understand the effect of socio-economic and demographic attributes on household water consumption. Low-, medium-, and high-income group housing falls under the category of *organized housing* the residents of which are the consumers of urban services, and urban local bodies are the service providers. Slums are *unorganized urban settlements* the residents of which enjoy urban services as beneficiaries of social schemes. The enumerators cautioned us that the data on household income are probably unreliable; therefore, we assumed that the sound correlation between housing category and income-class reported by Shaban and Sharma (2007) holds good even today. Family size was more variable in HIG and Slums and the average for all the groups was 4.25, a value close to the value of 4.39 reported by GNCTD (2014). More than half the family members in the surveyed households were adults, and about 85% of them contributed to the household income, although that proportion was lower in HIG and higher in Slum residents. Majority of people in organized housing worked in the service sector and showed no significant difference in occupation pattern (p= 0.0841) except that the higher the income category, the greater the proportion of self-employed skilled workers. Slum dwellers were mostly labourers or self-employed unskilled workers. No variation in educational status was observed in the organized housing category whereas in Slum residents had on average up to 8 years of schooling. A significant number of HIG and Slum residents obtain water from multiple sources: the HIG group typically used groundwater from tube-wells to augment the piped supply from DJB whereas for Slum dwellers, the major sources were tankers, private groundwater from privately owned tube-wells, and community taps. The organized housing category used alternative sources only when the supply from DJB was disrupted. Some households also used bottled water for drinking and cooking.

TABLE 1

Table 2 shows the frequency of, and time spent on, various water-consuming activities, namely bathing, storing water for drinking and for cooking, washing the dishes, washing clothes, toilet flushing, cleaning the house, and minor activities (grouped together under the heading ‘others’) such as watering plants and filling flower vases, brushing, shaving, hand washing, and vehicle cleaning. None of the household surveyed had a private garden. Those living in organized housing were similar in terms of the frequency and duration of the activities whereas in the case of Slum dwellers, the frequency was less and the duration was shorter. Activities under the *Others* category were all individual activities.

TABLE 2

Table 3 shows the similarities and differences in different socio-economic segments in terms of devices and processes used in water-consuming activities. In most households, people fill a bucket with water for bathing and wash themselves down, using a mug to draw water from the bucket: showers and bath tubs are limited to some households in the HIG category, and even in these households, not all members of the household prefer to use them. A significant number of households in organised housing use various types of water purifiers. High income households prefer reverse osmosis (RO) based water treatment systems. Similarly, washing the dishes and pots and pans under a running tap is the preferred method; where piped supply is not available, mostly in Slums, utensils are cleaned by keeping them in standing water, in a bucket, and rinsing them a couple of times by filling the bucket with fresh water each time. This method is neither particularly hygienic nor safe.

Residents of organized housing use flush toilets whereas nearly 60% of the surveyed houses for Slum dwellers do not have a toilet at home: the residents either use shared or public toilets (mostly women) or defecate in the open (mostly men). Similarly, the use of washing machines is growing among the residents of organized housing: several models are used, semi-automatic machines, in which clothes have to be rinsed manually, being more common than fully automatic machines.

TABLE 3

Respondents from organized housing complained about intermittent water supply and low pressure in the mains and did not consider the water to be of good quality or safe for drinking without treatment. To cope with intermittent water supply, water is stored in rooftop water tanks of capacities ranging from 250 L to 2000 L per household. To make up for the low pressure in the water distribution network, many households use booster pumps to draw water from the supply lines and lift it to fill the rooftop tanks. Approximately 83% of the households in organized housing and 8% households in Slums uses booster pumps of 0.5–1 hp capacity (short for horse power, 1 hp being approximately 0.75 kW) and run them for about 50 minutes a day (σ = 14 minutes). Households that use bore-wells as an additional source of water use 1 hp motors and run them for 10 minutes a day (averaged over a week).

Nearly 80% of the respondents from organized housing and approximately 57% from Slums do not find the quality of DJB-supplied water to be reliable. To avoid risks to health due to poor-quality water, people use domestic water purifiers or use bottled water. Amongst the households that use domestic water-treatment systems, those based on reverse osmosis (RO) are more common in HIG and among Slum residents whereas filtration and disinfection using ultraviolet (UV) radiation is more common in MIG and LIG. Households that use RO are mostly those that use groundwater as an additional source of water.

Households in organized housing spent on average INR 355 (σ = INR 86) a month on water and EWS spent INR 213 (σ = INR 98). Approximately 93% respondents reported payments to DJB as the principal expense on water. In general, respondents did not perceive the money spent on measures to compensate for poor quality (domestic purifiers) and for inadequate supply (booster pumps, rooftop tanks, and bore-wells) as part of the cost of water.

Table 4 gives the water consumption – based on actual measurements – for various activities. Table 5 gives a breakdown of the same data by the category of housing. The average consumption was 75.9 lpcd in organized housing but only 45.2 lpcd in Slum dwellers. The average consumption in Delhi is 63.9 lcpd. These estimates do not account for water lost in leakages because this study aims to estimate the water required to meet basic needs. The largest share (approximately 32%) was claimed by bathing, followed, in that order by toilet flushing, washing dishes and pots and pans, and washing clothes.

TABLE 4

TABLE 5

Within organized housing, water consumption among the three categories was compared using Wilcoxon test because the variables did not follow normal distribution. Water consumption did not did not differ significantly between housing categories (*p* valuebetween HIG and MIG Mean = 0.063 and HIG and LIG Mean = 0.0927), an observation contrary to the conclusions of earlier studies, which found water consumption to be positively correlated to household income (Beal et al., 2013). Increasing use of appliances in all income categories is one likely explanation for this outcome. Water and energy consumption of various water-consuming activities and appliances as measured experimentally is shown in Fig. 1. Bathing by the bucket-and-mug method and using dishwashers and fully automatic washing machines can reduce water consumption; however, the machines consume more electricity. Domestic water purifiers, on the other hand, increase the consumption of both water and electricity, because people tend to discard the unused stored water of the previous day. However, the impact of domestic water purifiers on domestic household water consumption is not significant because such stored water for drinking and cooking accounts for less than 10% of the total household water consumption. The method of bathing could affect water consumption substantially, although not many respondents preferred the more water-intensive method.

FIGURE 1Impact of water-use behaviour on water and energy consumption.

Family size also influenced per-capita daily water consumption (Fig. 2): it was the lowest in single-occupancy houses; increased gradually with family size up to a family of four, and then decreased in larger families. The findings are again contrary to the earlier findings, which reported a steady and consistent decrease in per-capita consumption as family size increased, perhaps due to the economies of scale (Arbués et al., 2010). We found that low-occupancy homes mainly have working adults, who are away for many hours at a stretch during the day and also prefer to outsource many of the water-consuming activities such as laundry (78% and 72 % households with single and double occupancy respectively outsource laundry) and cooking (57% and 34% households with single and double occupancy respectively outsource cooking). Large families are more likely to use water-saving appliances (43% households with family size of 4 and above do so and it is about 8% in all households having family size less than 4), which accounts for the slight decrease in per-capita water consumption.

FIGURE 2Relationship between family size and per-capita water consumption.

Water consumption of Slum dwellers was only 60% that of organized housing residents although many families in slums had children who were home most of the day. Yet, that lower per-capita water use is at the cost of sanitation and hygiene: washing up using stored water may consume less water but dishes washed under a running tap are cleaner; skipping a bath, washing clothes less often, and using non-flushing toilets, again, may save on water but are not hygienic practices. Slum households also showed wider variation in overall water consumption than those in organized housing because some Slum dwellers' households did have access to piped water and bore-wells.

Table 6 shows the electricity consumption of various water-consuming household activities. The average monthly electricity consumption per capita was 2.6 kWh and that of residents of organized housing alone was 3.25 kWh. A family of four living in organized housing consumed 10–16 kWh/month (the median value was 15 kWh/month). More than 50% of this electricity was used in coping with low pressure in the water distribution network and in augmenting the inadequate supply by pumping groundwater from bore-wells. Using water purifiers to make up for the unreliable quality of water consumed about 15% of the total electricity spent on water-related activities, and remaining electricity consumption was for activities that have the potential to save water. The cost of coping with inadequate water supply and unreliable water quality was approximately INR 172 a month in organized housing: INR 60 on electricity and INR 112 on maintenance of domestic water purifiers and rooftop water tanks.

TABLE 6

If one considers the behaviour of residents of organized housing as appropriate from the view of health, sanitation, and hygiene, the expected requirement would be 76 lpcd (p = 0.042); this value would be 78.3 lpcd (p = 0.037) if neither dishwashers nor washing machines are used and 77.9 lpcd (p = 0.028) if domestic water purifiers are done away with. Similarly, under the condition of judicious use of water – all residents use dishwashers and washing machines, take baths using a bucket and a mug, and give up using domestic water purifiers – the basic water needs can be met with 70.6 lpcd (p = 0.034), although it also means that monthly per-capita electricity consumption increases by 4.28 kWh. Therefore, a family of four can save as much as 1 kL of water a month, although at the cost of increasing its electricity consumption by 1.75 kWh a month—which can be avoided if water supply is adequate, reliable, and safe, making it possible to do away with booster pumps, overhead tanks, bore-wells, and water purifiers.

6. Conclusions

Changing lifestyles and greater use of technology by urban households have impacted both water and electricity consumption. The dominance of the tertiary sector in the economy and the global economic down turn have led to urban adults working longer hours away from home, thereby shifting their demand for water from the domestic sector to the institutional and commercial sectors. The number of households switching to electrical appliances such as dishwashers and washing machines to save time continues to rise: although this trend reduces water consumption, it also increases electricity consumption at the same time. Thus, water-saving measures are negatively correlated to electricity consumptions at the level of end users. Strategies for coping with inadequate quantity and unreliable quality of water increase the demand for water as well as electricity in the domestic sector. Those who cannot afford the additional expenses to cope with these shortcomings in water supply– slum dwellers, for example – -end up paying in terms of health, sanitation, and hygiene.

Within organized housing, water consumption did not differ significantly with income. The basic water requirements of a resident in Delhi were 76–78.3 lpcd. Bathing claimed a major share of household water consumption, although the majority used a bucket and a mug for bathing, which requires less water than that for a shower or a bath tub; this practice, together with the fact that most do not have private gardens, make per capita water consumption in Delhi lower than that reported in the literature for many developed countries. Electricity consumed by households on water-related activities amounted to about 15 kWh a month. Of this electricity, about 11 kWh (70%) is used only to make up for the deficiencies in water supply. Domestic water consumption in Delhi is likely to stabilize at approximately 71 lpcd as the use of such appliances as dishwashers and washing machines (which use water more efficiently) increases and the quality of water supply by DJB improves; however, these improvements also mean greater electricity consumption. Thus, there is the hidden cost of coping with deficiencies in water supply, although most households do not realize this. This analysis strengthens the case for rationalizing water tariffs with commensurate improvements in service by urban water utilities and for making a realistic assessment of the current water supply norms.

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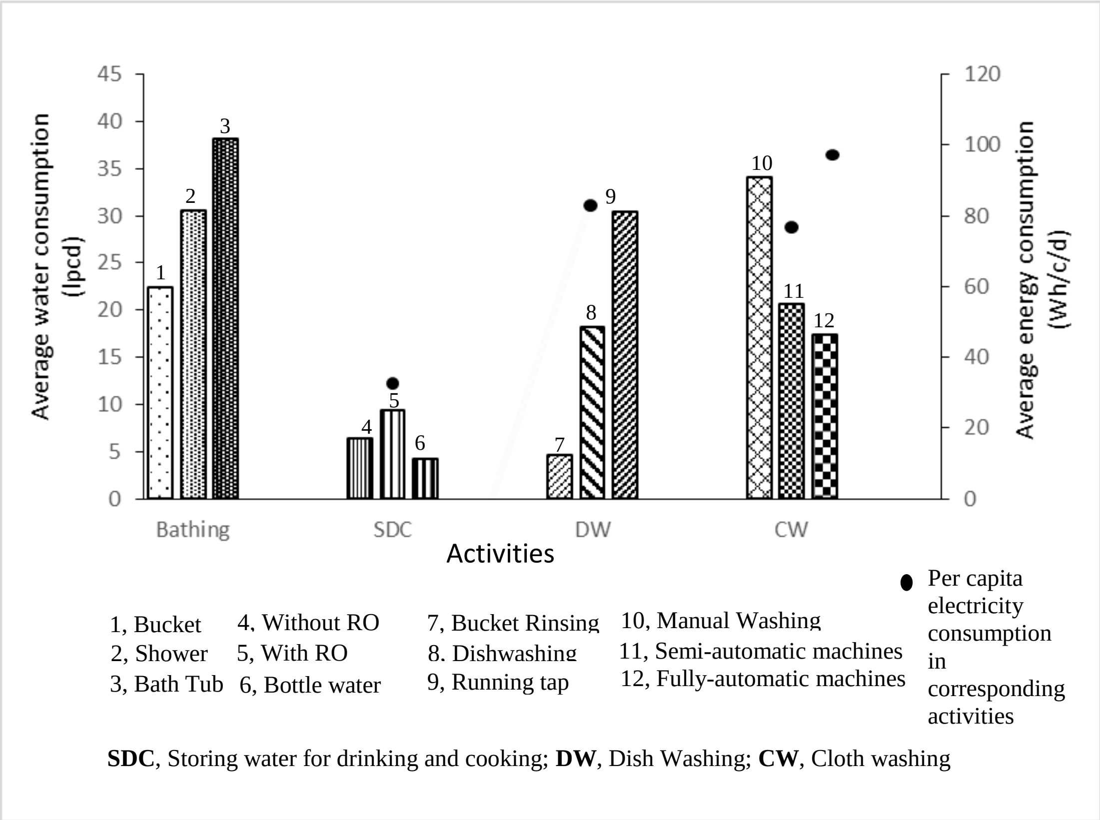

Fig 1. Impact of water-use behaviour on water and energy consumption.

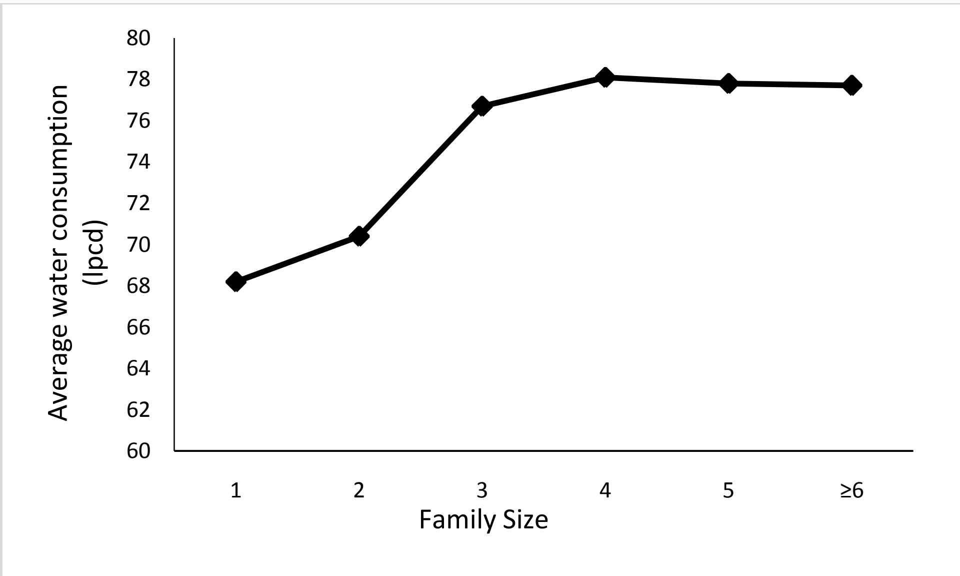

Fig 2. Relationship between family size and per-capita water consumption.

Table 1Socio-economic and demographic profile of sampled population.

Variable	Housing category			
	HIG	MIG	LIG	Slum dwellers

Sample size	122	146	112	116
Household profile				
Mean family size (σ)	4.12 (1.56)	4.06 (1.24)	4.25 (1.16)	4.64 (1.48)
Adult members in family (%) (rounded median value)	54	61	58	49
Family members contributing to household income (%) (rounded median value)	42	53	48	47
Age of family members (%) (rounded median value)				
< 18 years	46	39	42	51
> 50 years	26	31	29	16
Occupation of main earning member of the family (%)(rounded median value)				
Salaried employment	66	71	74	49
Executive, senior level	22	23	23	Nil
Executive, middle level	19	17	18	Nil
Executive, junior level	18	19	21	2
Clerical	7	12	12	18
Labour	Nil	Nil	Nil	29
Business	34	29	26	51
Self-employed skilled worker	18	17	13	6
Self-employed unskilled worker	Nil	1	5	42
Trader or shop owner	12	8	5	3
Industry	4	3	3	Nil
Source of water (%)				
Multiple sources	82	51	23	85
Piped water	100	100	100	9
Groundwater from tube-wells	21	12	4	29
Tankers	Nil	Nil	8	36
Bottled water	11	14	12	12
Community tap	Nil	Nil	3	24

Table 2Frequency (per week) and duration (min) of water-consuming activities.

	Water-consuming activity						
	Bathing	Storing for drinking and cooking	Washing dishes and pots and pans	Washing clothes (manually)	Toilet flushing	Cleaning the house	Others
HIG							
Frequency*	9	10	16	6	112	8	NA
Duration**(σ)	8 (2)	NA	36 (8)	82 (61)	NA	NA	NA
MIG							
Frequency*	7	10	14	9	106	7	NA
Duration** (σ)	7 (2)	NA	34 (19)	80 (60)	NA	NA	NA
LIG							
Frequency*	8	11	12	9	104	8	NA
Duration** (σ)	7 (2)	NA	33 (27)	84 (46)	NA	NA	NA
Slum dwellers							
Frequency*	7	7	10	7	72	5	NA
Duration** (σ)	6 (2)	NA	19 (7)	40 (26)	NA	NA	NA

*Median value, **Values rounded off, NA = not applicable

Table 3Devices and processes using in water-consuming activities. (All numbers are percentages of the surveyed households)

Activity	HIG	MIG	LIG	Slum dwellers
Bathing				
Bucket and mug	84	88	93	100
Shower	13	11	7	Nil
Bath tub	3	1	Nil	Nil
Storing water for drinking and cooking				
Without domestic treatment	16	19	23	74
With domestic treatment				
Filtration only	4	3	12	Nil
Filtration + UV (ultraviolet light for disinfection)	3	34	38	9
Filtration + RO (reverse osmosis)	14	21	11	16
Filtration + RO + UV	63	23	16	1
Washing dishes, pots and pans				
Washing and rinsing in standing water, using buckets	Nil	Nil	Nil	27
Running water	97	100	100	73
Dish washer	3	Nil	Nil	Nil
Washing clothes				
Manual	4	23	24	100
Semi-automatic machine	38	46	45	Nil
Fully automatic machine	58	31	31	Nil
Toilet flushing*				
Bucket	Nil	Nil	Nil	87
Flush toilets	100	100	100	13

*percentage estimated for houses that has attached toilets

Table 4Water consumption of different activities as actually measured. (Value in brackets is the standard deviation)

Activity	Per activity: Average water consumption (L)	Per activity: Rated power of the appliance (W)	Per activity: Duration of use of appliance (h)
Bathing			
Bucket and mug	24.6 (4.3)		
Shower	29.3 (7.4)		
Bath tub	38.7 (5.3)		
Storing water for drinking and cooking			
Without treatment	28.3 (5.9)		
With domestic treatment			
Filtration + UV	34.6 (4.9)	40	0.34 (0.06)
Filtration + RO	57.9 (8.4)	60 (80 with UV)	0.61 (0.13)
Washing dishes and pots and pans			
Washing and rinsing in standing water, using buckets	43.1 (5.4)		
Running water (per minute)	3.3 (0.24)		
Dish washer (one cycle)	45	320	1.1 (0.32)
Washing clothes			
Manually (per minute)	2.6 (0.13)		
Semi-automatic machine (one load of clothes)	54.6 (11.2)	230	1.13 (0.29)
Fully automatic machine (one load of clothes)	48.3 (5.8)	320	1.82 (0.38)
Toilet flushing (per flush)			
Bucket	7.4 (1.2)		
Flush toilets	5.5		

Table 5Average water consumption (litres per capita per day) for various activities, by category of housing. (Value in brackets is the standard deviation)

Activity	Organized housing				Slum dwellers	Overall average
	HIG	MIG	LIG	Pooled data		
Bathing	28.1 (12.7)	24.2 (11.4)	23.6 (12.2)	24.9 (12.8)	14.3 (12.8)	19.6 (10.3)
Storing water for drinking and cooking	7.1 (3.6)	6.4 (3.4)	6.1 (3.4)	6.5 (3.3)	3.9 (2.9)	5.1 (3.8)
Washing dishes and pots and pans	10.1 (8.8)	11.3 (7.8)	11.9 (6.1)	11.4 (6.7)	6.7 (6.4)	10.1 (6.9)
Washing clothes	9.1 (6.9)	10.2 (5.9)	10.8 (6.8)	10.2 (6.4)	8.2 (7.6)	9.4 (6.7)
Toilet flushing	15.6 (9.4)	14.4 (8.3)	14.4 (8.4)	14.4 (8.6)	7.3 (6.7)	12.1 (7.4)
House cleaning	4.6 (3.2)	4.2 (3.1)	4.1 (3.2)	4.3 (3.9)	2.1 (1.9)	3.7 (1.9)
Others	4.1 (2.7)	4.2 (2.6)	4.2 (2.7)	4.2 (2.7)	2.7 (0.5)	3.9 (2.6)
Total	78.7 (21.7)	74.9 (18.2)	75.1 (19.9)	75.9 (14.7)	45.2 (26.1)	63.9 (14.1)

Table 6Daily per-capita water-related energy consumption (Wh) of households. (Value in brackets is standard deviation)

Activity or device	Housing category				Overall average
	HIG	MIG	LIG	Slum dwellers	
Booster pumps and bore-wells	81 (49)	64 (45)	57 (52)	13 (11)	51 (39)
Washing clothes	31 (22)	25 (33)	14 (13)	Nil	23 (25)
Washing dishes and pots and pans	0.9 (0.5)	Nil	Nil	Nil	Negligible
Domestic water purifiers	19 (9)	16 (10)	16 (8)	6 (7)	13 (9)
Total	132 (37)	105 (37)	87 (37)	19 (10)	87 (31)